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AN EXPERIMENTAL STUDY OF VISUAL MOVEMENT AND THE PHI PHENOMENON

BY
FORREST LEE DIMMICK

Thesis presented to the Faculty of the Graduate School of
Cornell University in partial fulfillment of the requirements
for the degree of doctor of philosophy

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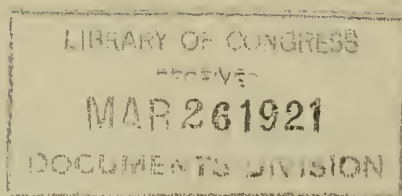
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By F. L. DIMMICK

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INTRODUCTION

In his "Experimentelle Studien über das Sehen von Bewegung"² Wertheimer reports the isolation of a new elementary mental experience, that of movement. To keep it distinct from the perceptual complex in which it usually occurs, he calls it *Phi* or the *Phi phenomenon*. Analysis of it reveals nothing for him but just the movement-experience; it has no visual quality; it has only spatial localization and direction.

The aim of our investigation is to put this elementary movement-experience, this *Phi* phenomenon, under critically descriptive conditions, and to test its analysability.

The term 'movement sensation' has been in common usage for a long time. Exner³ first gave to it the meaning, in a pregnant sense,

¹ From the Psychological Laboratory of Cornell University.

² M. Wertheimer, Ueber das Sehen von Bewegung, *Zeit. f. Psych. u. Phys. d. Sinnes.*, 1 Abt. 61, 1912, 161.

³ S. Exner, Ueber das Sehen von Bewegungen, *Wiener Sitz. Ber.*, Abt. 3, 72, 1875, 156.

of a primary and elemental experience. He cites experiments to demonstrate its immediacy, and points out its fulfillment of the characteristics of sensation. The peculiar nature of the movement experience was again emphasized by Schumann,⁴ and an experiment to demonstrate its simplicity was indicated. Wertheimer followed closely the cue given by Schumann. He chose the simplest conditions under which the impression of movement could be obtained. Two lines, differing in position, were presented successively in the Schumann tachistoscope. The principal stimuli were a pair of parallel horizontal lines, and a pair of lines set at an angle to each other. A number of variations of these two stimuli were made in order to test the effect of different conditions. The *O*'s seem not to have been given specific instructions, but to have been allowed to report spontaneously what they experienced. They were, of course, kept in ignorance of the nature of the stimulus. Only three *O*'s were considered necessary, both because those with whom the work was started agreed well with one another, and because the reports were immediate.

The important determinant for movement, with the above stimuli, Wertheimer finds to be the temporal interval elapsing between the presentations of the two members. There is an optimal time, 60 , at which the movement of a line all the way from the one position to the other results. With intervals either larger or smaller, the movement experienced is not complete. As a rule two objects are seen, both moving more or less, but not moving over the entire field. Such an experience we shall call bimembral movement. It sometimes happens that only one of the members seems to move, while the other remains stationary. This experience may be designated unimembral movement. A fourth type of movement is that in which there is no change of position of either member, but only a movement within a member itself, an intramembral movement. Under occasional or demonstrational conditions, Wertheimer is able to get the movement-experience alone, independent of any substantive perception and with no visual quality. Because it can thus exist in its own right, it is given the designation *Phi* or the *Phi*-phenomenon. It is this *Phi*, then, which, when added to the perception of a line in two successive positions, gives the impression of movement. It is the basis, too, of that seen movement which is correlated with a physically moving stimulus. The observations which he made led Wertheimer to outline a physiological theory of a short-circuit of nervous excitation in the cortex⁵ as the basis of the *Phi*-phenomenon.

EXPERIMENTAL PROCEDURE

For our experimental work, we used a modification of the Dodge tachistoscope which enabled us to present successively the two members of a bimembral stimulus. In addition it gave us control over the pre- and post-exposure fields.

The particular modification which we made of the Dodge instrument was the addition of a third stimulus-field by insertion of a second transparent mirror. A group of three plain-glass nitrogen-filled lamps (two 200 watt, and one 100 watt) furnished illumination for the stimulus-fields. They were placed at the ends of a set of three parallel tubes of about 5 cm. diameter. The light conducted down the tubes

⁴ F. Schumann, *Ber. ü. d. II Kong. f. exp. Psychol.*, 1907, 218.

⁵ *Op. cit.*, 248.

was reflected from mirrors to the respective stimulus-fields. Between the lamps and the open ends of the tubes was placed a falling shutter, so designed that the exposures of the three fields were independently variable. The openings through which the light entered the tubes were horizontal slits, 1 cm. by 4 cm. To give additional control, an auxiliary shutter was set in every tube a little way from its open end, and with it a diaphragm which made possible the equation in sensible brightness of all three fields. The shutter fell from a constant height by its own weight when the current was broken through an electromagnet. The friction, as the falling shutter ran in the guides, was slight and the variation in time of fall proved negligible.

This arrangement made it possible for us to start with any pre-exposure field, to present the first member of the stimulus for a given length of time, then after a variable interval (during which the pre-exposure field was repeated) to present the second member for the desired length of time, and then to return to the pre-exposure field.

The shutter permitted of total times up to 380σ ; 210σ was the longest needed. The eye-piece of the exposure apparatus was inside a dark chamber, and the *O* was allowed 10 min. to become partially dark-adapted before work was begun.

All of the stimuli described by Wertheimer were repeated, and six object-pictures of our own were added. The greater part of our work was done with two arrangements, the one of which gave movement from an oblique to a horizontal position, and the other from an upper horizontal to a lower horizontal position. There were four pre-exposure fields: A, uniform white, identical with the background of the stimulus-cards; B, similar to A, with a black fixation-point at the middle of the field; C, uniform lightless field; D, unlighted field, bounded at the top and bottom by luminous lines.

The exposure-time for each member of the stimulus was kept constant at 30σ . The time-intervals were 30σ , 90σ , 120σ , 150σ . They cover the range given by Wertheimer from near simultaneity to the region of succession. The principal stimuli, the angle and the horizontals, were presented in series of five exposures with every pre-exposure field, at every time, and to every *O*. Four other stimuli were presented to every *O* in the same sort of series, but with only two of the pre-exposure fields; they were so chosen that every stimulus was studied by one or two *O*'s and with two to four pre-exposure fields. A haphazard order of fields, times, and stimuli was followed in the presentation of the series.

Two different sets of instructions were given to the *O*'s, thus duplicating the above set of series. The one of these, which we shall call the 'process' instruction, was: "A stimulus will be shown you which will arouse a visual perception. Describe this perception in strictly psychological terms as accurately as you can. Report no process of which you are not sure. The stimulus will be repeated to complete the descrip-

tion." The other set, the 'meaning' instruction, ran: "A stimulus will be shown you which will arouse a visual perception. Characterize this perception as fully as you can. The stimulus will be repeated to complete the characterization." To three *O*'s the process-instructions were given first, and the entire group of series was repeated with the meaning-instructions. Three other *O*'s were required to give meaning-reports first, and were then shifted to the process-attitude. The two most practised *O*'s were instructed in successive series either for process or for meaning by chance, and every series was repeated later with the alternate instructions. Except for the last two, the *O*'s were required to read the instructions at the beginning of every observation hour. Before the regular work was begun, trial series were taken until the reports gave evidence of adequacy and stability.

The eight *O*'s who served were: Miss C. Comstock (C), graduate student in psychology; F. L. Dimmick (D), assistant in psychology; Dr. L. B. Hoisington (H), instructor in psychology; Miss M. F. Martin (M), graduate scholar in psychology; Miss A. H. Sullivan (S), graduate fellow in psychology; S. A. Takaki (Ta), graduate student in psychology; S. A. Tung (Tu), graduate student in psychology; and Mrs. A. K. Whitchurch (W), graduate student in psychology. Observers C, D, H, and S were practised; M, Ta, Tu, and W were relatively unpractised.

O sat with his head in the hood of the instrument. The auxiliary shutter was opened, a ready-signal given, the exposure shutter dropped, and the auxiliary shutter closed.⁶ *O* then gave his report according to the instructions. The exposure shutter was raised to the starting position, and the stimulation and report repeated, until the series of five was completed. A rest of 2 or 3 minutes was permitted while the apparatus was reset for a new series. The above procedure was followed for the 160 series with every *O*.

RESULTS

Table I summarizes quantitatively the results obtained with the two principal stimuli. Under our conditions, all *O*'s perceived optimal movement of the horizontal lines in more than 50% of the cases, and only one fell below that percentage with the oblique-to-horizontal movement. Of the perceptions

⁶ The function of the auxiliary shutter was to shut off all light from passing down the tubes save when a true exposure was made. It eliminated the possibility of a false exposure when the falling shutter was raised to its starting position.

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of partial movement, unimembral movement shows itself much more frequently than bimembral for all but two *O*'s. Simultaneity and succession occur but rarely. Closely paralleling the above perceptions are the percentages of reports, under the instructions to 'describe in psychological terms,' in which some visual process was present in the field between the two members of the stimulus. The number of times when the entire spatial interval was involved agrees with the number of optimal movements perceived; the frequency of cases in which the process in the interval accrues to one of the members and not to the other is approximately the same as that of the reports of unimembral movement; processes which involve both members but not the entire field occur as often as does bimembral movement.

TABLE I

PROCESS CONFIGURATIONS AND MOVEMENT PERCEPTIONS
(Percent. of 100 Reports for Every *O*)

Obs.	HORIZONTAL LINES								OBLIQUE LINE AND HORIZONTAL							
	Total		Uni-		Bi-		None		Total		Uni-		Bi-		None	
	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M
C	78	77	20	15	3	8	0	0	48	35	43	58	8	6	1	1
D	66	61	22	21	12	16	0	2	77	73	12	14	11	14	0	0
H	66	56	24	24	3	15	7	5	67	66	25	19	5	10	3	5
M	72	65	23	21	1	11	4	3	100	88	0	12	0	0	0	0
S	77	69	6	7	13	23	4	1	90	72	1	23	1	7	8	0
Ta	63	52	25	28	10	17	2	3	60	65	30	33	7	2	3	0
Tu	77	69	22	21	2	9	0	1	80	69	20	29	0	1	0	1
W	60	53	21	22	19	25	0	0	68	77	19	15	13	8	0	0
Average	70	63	20	20	8	15	2	2	74	68	19	25	6	6	2	1
Mean Var.	6	7	4	4	6	5	2	1	13	10	11	11	4	4	2	1

Uni-, Bi-, = experiences of unimembral and of bimembral movement.

P = Process configuration; M = meaning characterization.

TABLE II

OPTIMAL MOVEMENT WITH DIFFERENT BACKGROUNDS
(Percent. of 25 Reports for Every *O*)

Obs.	HORIZONTAL LINES								OBLIQUE LINE AND HORIZONTAL							
	A		B		C		D		A		B		C		D	
	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M
C	100	76	53	76	73	80	87	76	53	56	59	52	40	24	40	8
D	60	40	76	48	72	60	60	96	64	68	68	64	80	88	96	72
H	56	56	72	80	72	68	64	52	72	48	72	92	64	68	60	56
M	76	67	56	53	68	67	88	73	100	100	100	100	100	40	100	52
S	84	87	72	93	72	40	88	53	96	60	92	60	80	93	92	73
Ta	67	40	53	48	53	56	80	64	67	60	60	76	67	60	47	64
Tu	73	68	93	68	67	68	73	72	80	68	87	84	73	52	80	72
W	68	60	60	53	52	53	60	47	64	80	60	67	76	67	72	93
Average	73	62	67	65	66	62	75	67	78	68	75	74	73	62	73	62
M. V.	10	11	11	13	7	8	11	13	15	12	14	14	11	17	19	17

TABLE III

OPTIMAL MOVEMENT WITH DIFFERENT TEMPORAL INTERVALS
(Percent. of 20 Reports for Every *O*)

Obs.	HORIZONTAL LINES										OBLIQUE LINE AND HORIZONTAL									
	30		60		90		120		150		30		60		90		120		150	
	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M
C	67	55	92	95	92	90	83	80	58	65	25	0	62	50	75	70	50	35	25	20
D	50	75	90	65	80	85	80	45	30	35	70	45	95	90	95	95	70	70	45	65
H	55	50	80	65	80	75	65	60	50	30	50	65	90	95	90	90	55	75	50	30
M	50	75	75	92	90	75	75	75	70	8	100	83	100	100	100	100	100	100	100	58
S	60	83	90	92	95	92	95	42	45	33	100	92	85	100	95	92	100	42	70	33
Ta	50	70	83	55	92	65	42	35	50	35	50	50	83	60	92	100	50	75	25	40
Tu	75	70	100	95	100	85	50	55	58	40	75	75	83	90	100	80	90	60	50	40
W	15	25	70	75	90	83	75	42	50	42	60	67	70	92	100	100	80	67	30	58
Av.	53	64	85	79	90	81	71	54	51	36	66	72	84	85	93	91	74	66	49	43
M.V.	12	14	7	14	5	7	14	13	8	10	20	21	9	15	6	8	18	15	18	13

In Tables II and III the results have been arranged to indicate the influence of the pre- and intra-exposure field and of the temporal interval between members. Individual variations appear with the various fields, but they show no uniform tendency, and their nature is indicated in some cases in the introspections. C often objected that the fixation-point on pre-exposure field *B* interfered with her reports of process; S complained of the dark backgrounds. It is significant, however, that the process-reports and the perceptive characterizations parallel each other. This agreement is very evident when the averages for the group are taken, and it is further supported by the fact that the mean variations are not excessive. We may conclude, then, that the kind of pre-exposure field employed had no general and constant effect on the perception or its process-configuration.

Table III, on the other hand, brings out a very definite influence of the temporal interval. The *O*'s vary among themselves, but they agree in that they have curves of percentages which are high for the middle values of the temporal interval and low for the extreme values. Process-reports and perceptive characterizations run parallel. The averages, of course, show the conformity even more prettily. Time-interval 90 σ has the highest average percent. of optimal movement and of total configurations; 30 σ and 150 σ have the lowest. Just as significant is the fact that the mean variations are smallest at the middle value. The larger variations among *O*'s occur with the longer or shorter times.

The evidence of the values, in the above tables, of the various perceptive characterizations indicates unquestionably that we have reproduced the essential factors of Wertheimer's conditions. Table I shows that our temporal intervals lie between those which give succession and simultaneity. The two forms of partial movement appear frequently, but optimal movement

predominates. The ineffectiveness of variations of the pre-exposure field does not contradict Wertheimer's observation that the color of the stimulus did not affect the perception. Finally, the behavior of the perception with the different time-intervals is exactly that which Wertheimer suggests, though he makes no precise statement.

On the other hand, in the column in which Wertheimer would write 'nothing,' under the heading 'process,' we have found a closely parallel set of values which represent the configurations of visual process present in the movement-field when the *O*'s were set to describe the experience. The nature of the visual experience which filled the interval can be pointed out most clearly by direct reference to the introspections.

OPTIMAL MOVEMENT; MEANING REPORTS; STIMULUS I

C. A horizontal line appeared in the upper part of the field, moved down to a lower position, and stopped; the movement was slow, smooth, and continuous.

D. I saw a horizontal line move quickly from a position above the fixation point to one below, and disappear. It seemed to come in, move down, and go out, as if that were only a part of some larger movement. The movement was rapid but smooth.

H. A black horizontal line appeared and moved down very rapidly, and then came to rest in a lower position for a short time. The movement was uniform but very fast.

M. A line moved from an upper horizontal position to a lower one; it slowed up just before it reached the final position; the movement was continuous all the way from one to the other.

S. A rectangle moved down smoothly and stopped for an instant. The speed of the line increased as it moved, and was very rapid just before it stopped.

Ta. A horizontal line appeared in the center of the field and moved down smoothly; it became shorter as it moved, and stopped in a position lower down.

Tu. A line dropped downward very smoothly and rapidly, until it reached the lower position, and then disappeared.

W. I saw a line drop smoothly and quickly from one position to another.

STIMULUS II

C. I saw an oblique line which moved down across the field to the horizontal with a smooth and continuous movement.

D. A dark grey rectangle moved smoothly and rapidly from an oblique position to a horizontal.

H. An oblique line fell down into a horizontal position. The movement was continuous, but faster just before it reached the final position.

M. An oblique line moved down through an arc to the horizontal.

S. An object in the oblique position fell to the horizontal. The movement was rapid, and stopped short at the end.

Ta. An oblique line appeared, turned downward, and took the horizontal position. The movement was smooth.

Tu. I saw an oblique line first, and it moved steadily down into a horizontal position.

W. The oblique fell rapidly into the horizontal; I saw movement all the way.

PROCESS REPORTS; STIMULUS I

C. At the upper part was a black horizontal extent which immediately gave place to a grey patch below and joining it. The bottom of the grey was darker and at that place appeared later a black extent similar to the first. The grey changed in quality; it was one continuous extent, but it was different at different places.

D. A black line appeared just above the middle of the field. It disappeared, and extending down from where it had been was a grey band, light at the top and dark at the bottom, and at the lower side was a very dark strip of grey. The grey patch did not change in extent, but the patterning of brightnesses changed.

H. The upper line was not definite at the lower edge, but fused into a filmy grey that was a little darker at the right and left extremes, and terminated in a black process lower down.

M. There was a line of very dark grey at the top, and immediately below a darkening of the field in the general form of a rhombus, the edges of which were fuzzy but fairly definite. At the bottom of this figure was a definite line, and in the middle a darker streak which could hardly be called a line.

S. At the top was a black rectangle, clear and intense. Below was a grey patch, longer in the horizontal dimension, but not clear. At the bottom was a definite line.

Ta. At first an irregular rectangle, black and sharp at the top, appeared. Its lower side was grey and blurred. Below was a wide grey line, sharp at the bottom but indefinite above. The lower and upper sides of the upper and lower lines respectively shaded off and joined each other.

Tu. First, there was a line above the middle of the field; below it, a dark grey which faded out farther down until it reached a lower horizontal line, the upper part of which was grey and indefinite, the lower part black and sharp.

W. A horizontal line appeared and disappeared, and below where it had been there was a wide grey rectangle of light tint at the top, medium in the middle, and dark at the bottom. Below appeared a second line.

STIMULUS II

C. First there was a black oblique at the top, which immediately became greyer, and then was replaced by a grey patch, which extended down to the horizontal, where a line appeared.

D. The oblique came in first; then below it there was a grey which extended down to a horizontal line below; this grey was not uniform but light and dark in streaks.

H. An oblique line appeared and then a horizontal, and between them the field was grey in a solid fan-shape.

M. An oblique appeared; then below it there came a sector of pale grey which was darker near the bottom, where it became a more definite line. The first line had faded out before the last one came.

S. A black oblique line appeared; then something grey came below it which was rather indefinite, and extended down to the horizontal line.

Ta. I saw an oblique line which was blurred downward. The upper part was black and clear-cut. The lower part shaded off into a grey, at the bottom of which came a horizontal line.

Tu. I saw an oblique line and a horizontal, and the space between them was grey. The oblique was wide and had no definite outline on the lower side.

W. An oblique line appeared and disappeared, and then a horizontal came below. Between the two was a triangular light grey patch, which was darker near the bottom line.

UNIMEMBRAL MOVEMENT; MEANING REPORTS; STIMULUS I

C. A horizontal line moved down smoothly but not continuously. It moved part-way, then disappeared, then reappeared lower down and stationary.

D. The first line appeared and remained stationary. Below it another line came in, moving downward. The movement was over most of the space between the two positions, but was of the lower line.

H. A line appeared in the upper part of the field for an instant; then a little lower down something moved into the field, and stopped as a black line at the bottom.

M. A horizontal line came into the part of the field moving, then another appeared lower down and stationary.

S. A line moved down smoothly, getting faster as it went, and then the end-position stood out, sharp and stationary.

Ta. A line moved down, and as it moved another appeared lower down and remained stationary.

Tu. First I saw a line which wavered but did not change position, and at the same time there was something moving down into a position below.

W. A line dropped into a lower position. The motion was best near the bottom, and there was a blank space just below the top position.

STIMULUS II

C. An oblique and horizontal appeared, and the first moved down toward the second but never reached it.

D. I saw two lines, one oblique and one horizontal. The latter remained stationary, and the oblique moved down toward it, but was gone before reaching it.

H. An oblique line came in and moved downward, and below it stood a horizontal line.

M. An oblique line moved down toward the horizontal. The movement was jerky and definitely of the oblique, not of the horizontal.

S. I saw a line move down very rapidly through an arc. The first part of the movement was not clear, *i.e.*, it seemed to be part way down before I saw it; above was a blank.

Ta. An oblique line appeared, then a horizontal, and the oblique moved down to the horizontal.

Tu. An oblique line appeared in the upper part of the field and moved down faster and faster until I could not see the movement. Then the horizontal came in.

W. An oblique line moved rapidly to the horizontal. The movement was best at the beginning, and just at the bottom there was a space of no movement at all.

PROCESS REPORTS; STIMULUS I

C. I saw a black line; and below it was a grey band which was not uniform in quality, but which had no definite lines in it. Below was a second sharp black line.

D. Two lines came successively. The upper was clear-cut and stationary; the lower was at first a band of greys, the upper edge of which was indefinite and concave.

H. A black line appeared in the upper part of the field. Below and detached from it by a bright streak was a rather indefinite grey, which fused into a black line lower in the field.

M. First came a line in the upper part, then a grey, and another line below. The grey joined the lower line but was separated from the upper by a bright streak.

S. I saw a horizontal line, then lower down another with a grey patch above it.

Ta. The first line was wide; the upper part black, the lower part grey and blurred. There was a bit of white background between this and the lower line.

Tu. There was a sharp definite line. Just below it was white, and all the rest below was grey, darkening downward until it joined the lower line.

W. I saw two horizontal lines, one below and after the other. A band of greys extended up from the lower toward but not to the upper.

STIMULUS II

C. There was a wide patch of grey in the shape of a sector. It was dark at the top and shaded off into light grey downward. The grey did not reach to the horizontal line which came in at the bottom.

D. A sharply defined oblique line appeared and then a horizontal. When the horizontal came, the field just above it was greyish.

H. First there was an oblique line with a patch of bright field just below it; then at the bottom a narrow sector of light grey, which was later replaced by a horizontal.

S. A black oblique appeared first; below it was white. Then came a horizontal line, with an oblique grey on its upper edge.

Ta. The oblique was grey on its lower side and blurred downward. There was a white space between it and the horizontal line.

Tu. I saw an oblique line clearly; then the background below it became dark at the top and light lower down. At the bottom there was a horizontal line with a white streak above it.

W. A distinct oblique line appeared at the top, then a horizontal, and between them a series of grey triangles, light at the top and dark at the bottom and joined on to the lower line.

BIMEMBRAL MOVEMENT; MEANING REPORTS; STIMULUS I

C. A horizontal line moved down and stopped. The movement was not continuous; there was a place in the middle where it disappeared entirely. Farther down it came back again.

D. A horizontal line appeared and started to move, then disappeared, but reappeared lower down, and moved into the lower position.

H. A heavy black line appeared and started to move, but disappeared. Part way down it reappeared, and moved into the lower position and stopped.

M. Two black horizontal lines appeared and both moved down a little.

S. An object appeared and moved downward. A little way below another line appeared, and moved down and stopped.

Ta. A line appeared, moved down and disappeared; after a short space another appeared, and moved down and stopped.

Tu. A horizontal line moved down very rapidly, disappeared for an instant, then moved down again into the lower position. The upper part of the movement was the more rapid.

W. The line moved down quickly but with a flicker, *i.e.*, it started to move, there was a break, then the last part of the movement came out distinctly.

STIMULUS II

C. An oblique line moved down to the horizontal. The movement was not smooth; it disappeared in the middle so that there was a blank space.

D. An oblique appeared and began to move, but very soon disappeared. Then a horizontal appeared, which seemed just at the end of a movement down.

H. The oblique started moving, then for a bit I saw nothing, then the line moved from just above into its horizontal position.

S. An oblique line moved down to the horizontal, but there was a pause in the movement part-way down.

Ta. An oblique line came in and started to move, but soon faded out; then something below jumped in, and moved down to the horizontal.

Tu. An oblique line moved down to the horizontal but not smoothly; there was a flash of good movement at the beginning and end.

W. An oblique line dropped to the horizontal, but I did not see movement all the way. There was a blank in the middle.

PROCESS REPORTS; STIMULUS I

C. I saw a line in the field above the middle. Its edges were not sharp, and it shaded off at the lower side. Below appeared another line, which was surrounded with grey at first and then became quite distinct.

D. A horizontal line came in with a grey blur on the lower side. The grey extended farther down from the extremities of the line than from the middle, so that its lower side was concave though not sharply outlined. The second line had a similar grey above it. A roundish patch of white background was left between the two.

H. I saw a black line a little above the middle of the field, then another below the middle and equal in extent to the first. Between was a grey, with a slight gap of bright field in it.

M. There appeared two lines of grey. Both were indistinct on the edges that were toward each other.

S. I saw a line that was clear and black at the upper edge but indistinct below. Then came a space in which there was nothing, and then I saw a hazy line at the bottom.

Ta. The first line was grey all over and a little wider at the ends; the middle part had no definite outlines. The second line had black and clear outlines at the ends but the middle part was indefinite at the top, and the grey margin of it was a little concave.

Tu. First an upper and then a lower horizontal appeared, and the space between was grey except at the center, where it was the same as the background.

W. I saw a horizontal line, then another below it. Between them was a blur of grey, darker at the top and bottom and white in the middle.

STIMULUS II

C. I saw an oblique line. It disappeared and the field was only white, then a horizontal appeared. Both lines were indistinct and blurred toward the interior of the angle.

D. I saw an oblique line. It disappeared and I saw a horizontal. The oblique was at first a sharp line, then it shaded off into the background below it. The horizontal was indefinite along its upper edge when it came.

H. An oblique line appeared which was not sharply outlined. Just below it was a very light grey. Then a horizontal appeared, which was indefinite on its upper edge at first but soon became sharply outlined.

S. First there appeared an oblique line, which was not clear at the lower edge but shaded off into grey. Below there was an interval of white, and at the bottom a horizontal which also lacked definition.

Ta. The upper side and end of the oblique had clear-cut outlines, but the lower side was greyish and blurred down. The upper side of the horizontal had no definite outline.

For the demonstration of bimembral movement, Wertheimer recommends a stimulus consisting of two squares for the first member and a horizontal line for the second. This stimulus aroused bimembral movement in 94% of the times it was presented to our *O*'s and corresponding process-configurations in 84% of the times it was given under the process-instructions. The typical reports are as follows:

MEANING REPORT; SPECIAL STIMULUS

C. I saw a horizontal line and above it two squares. All three moved down a little and then disappeared.

PROCESS REPORT

C. Two squares appeared in the upper part of the field. They were grey and indefinite at the bottom. Below them came a black horizontal line, which shaded off into grey at the top.

The parallel values for the percentage of the three forms of movement are sufficient evidence that every perception of movement of these sorts has a corresponding process-configuration. The conclusion is further substantiated by the fact that in a number of reports the *O*'s have stated that a certain movement had a particular process-aspect and conversely that when, for instance, the grey was spread over the whole field, the movement was best.

Wertheimer's fourth movement phenomenon, intra-membral movement, appears according to his statement in the stage of simultaneity. Our *O*'s, likewise, reported a number of cases, when the temporal interval was shortest, in which the lines stood still, but in which there was a quick "jerking back and forth" or an "unsteadiness" as if the line moved inside itself. Under similar conditions, with the instruction to report process, the lines were sometimes of a multiform grey, variously patterned. Further analysis of intramembral movement, with the stimuli which Wertheimer says are especially favorable for its arousal, confirms what we have already said. Typical reports are as follows:

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INTRAMEMBRAL MOVEMENT; MEANING REPORTS; STIMULUS III⁷

C. The line seemed to double over on itself at the middle; that is, there seemed to be a smooth gliding movement from left to right within the line which did not, however, change position.

W. I saw a horizontal line in which there seemed to be movement across, left to right. It was not movement from one position to another, for there was only one line and the movement was within it.

STIMULUS IV⁸

S. There was a square which contracted and expanded as if it were elastic.

Ta. A square appeared and stretched to right and left.

STIMULUS V⁹

M. An oblique line appeared and shrank towards its upper end until it became almost a square.

Tu. There appeared a line in the oblique position which seemed to move toward its upper end, but did not change its general position.

PROCESS REPORTS; STIMULUS III

C. I saw a horizontal line which was black at the right end, dark grey at the left, and light in the middle. The left-hand part was not evenly outlined, and there was no definite line where it joined the black part.

STIMULUS IV

S. First a black square appeared; then in its place was a greyish rectangle longer in the horizontal, then one darker and longer, then one black and slightly shorter.

Ta. I saw a black square which was fairly clearly outlined at first. Then it became greyish, and to the right of it was a horizontal line of dark grey. Then the whole figure was a horizontal line black at the left end and lighter toward the right.

STIMULUS V

M. An oblique line appeared. Then it was lighter at the lower end, and shaded into a dark grey upward. At the top was a sharp black square.

Tu. First I saw a dark grey oblique line; its upper end was darker, with a light place just below it. The lower part of the figure faded out into a light grey.

Movement within an object without change of position of that object thus presents nothing new. Under the characterization-attitude, it is movement on a par with the change of position of a form or object; descriptively, it is reflected in consciousness as the visual quality grey.

⁷ Stimulus III consisted of two horizontal lines, the second of which was in a line with but to the left of the first.

⁸ Stimulus IV consisted of a square and a horizontal line of the same width. The centers of the two forms came at the same point.

⁹ Stimulus V consisted of an oblique line and a square of the same width. The square came at the upper end of the position of the line.

THE PURE PHI PHENOMENON

Finally, a number of cases of Wertheimer's pure Phi were reported by our O's. Frequently the line was not seen during the movement; there was simply "something moving" or just "movement." Sometimes neither of the lines was clearly perceived; just a bit of movement downward. The cases in which both lines were perceived with only movement between are entered in Table I as optimal movement, and are paralleled by total process-configurations. The appearance of movement detached from its object occurred, as Wertheimer notes, when the stimulus was new or for some other reason was incompletely perceived. Under exactly these same conditions, but with the instructions to report process, our O's noted a flash of grey without the usual limiting lines above and below.

OBJECT-STIMULI

The remaining stimuli which were given by Wertheimer and which we repeated yield results agreeing with those already reported, but add nothing new to our analysis of the perception of movement. The six object-pictures which we added to Wertheimer's list showed the effect of central associations by giving optimal movement over the whole range of our conditions, and total configurations of process in all but a very few cases.

COLORED STIMULI

In the description of the stimuli used in his experiments, Wertheimer tells us that he varied the color of the members. In another place he remarks that partial movement results when the two members are not of the same color. Aside from this, the implication is that one color gives movement as well as another. After our main series had been completed, we presented stimuli of various colors to our O's. The stimuli were shown in series of ten exposures at the optimal time (90σ) and with a pre-exposure field of the same quality as the background. The colors of these stimuli were red, green, and blue on white backgrounds, white and yellow on black backgrounds, red on a green background, and blue on a yellow background.

Movement, optimal in all but a few cases, was reported by all O's for all colors and backgrounds when the instructions were to 'characterize.' Under the descriptive attitude there was always noted a *grey* patch covering the space between the two members. When the backgrounds were white or a light color, the grey was a little darker than medium. On the black field it appeared whitish. We may state, then, with assurance

that the grey which is the psychological equivalent of the perceived movement is under our conditions independent, for its quality, of the quality of the members of the stimulus, but shows an influence of the background which has the appearance of a brightness-contrast effect.

KORTE'S REVERSE MOVEMENT

Korte,¹⁰ in a later investigation, studied the perception of movement backward from the second member to the first, which, he said, resulted from making the second member more "intense" and by directing the attention to it. He varied "intensity" either by making the second member wider than the first, or by putting short perpendiculars across its ends. With an increase in "intensity" merely, only a slight backward jerk appeared. Neither was attention to the second line sufficient alone; but with an increase of "intensity" and a direction of the attention to the second member, the backward movement was plainly evident.

We attempted to repeat Korte's conditions. Our stimuli with members of different "intensities" were a grey line on white followed by a black line of the same width; a grey line on black followed by a white line of the same width; a black line of 1 mm. width on a white background followed by a black line of 4 mm. width; and a white line on black followed by a line of the same size with short perpendiculars across the ends. At first the *O*'s were given the usual meaning-instructions, and a series of ten exposures was presented. Then they were instructed to attend to the more "intense" line, and ten more exposures were made; and finally they were asked to try to get the line to move from the more "intense" position to the other. The perception was always from the member presented first to the second, save for a very few instances with the third instruction when *O* reported that perhaps there might be a hint of a jerk backwards; but even then no positive movement, such as they had seen with the other stimuli, was perceived.

We have repeated Korte's conditions as nearly as his description of them permits; and to his stimuli, which give spatial and form insistence, we have added intensive insistence. Since we never get a positive movement-perception as we do under Wertheimer's conditions, it seems evident that we are not in the presence of compulsory conditions, and that the two perceptions are not of the same order.¹¹

THE NATURE OF THE PROCESS-CONFIGURATION

Now that we have pointed out the quality of the psychological correlate of Wertheimer's Phi, we must emphasize that this is but one of its attributive aspects. It must not for a moment be assumed that it is a simple text-book grey, the grey that lies at the center of the color-pyramid, or the grey of a piece of grey paper. The temporal attribute is beaten up with

¹⁰ A. Korte, *Kinematoskopische Untersuchungen*, *Zeit. f. Psych. u. Physiol. d. Sinnes.*, 72, 1915, 193.

¹¹ We are engaged in further experiments of this kind, the results of which will be reported later. We are also repeating certain experiments of F. Kenkel and V. Benussi.

the quality into an integration of the first order. All O's describe the experience as a "flashing," "flickering," "unsteady," "shimmery," "flame-like," "liquid," "live" grey. It is further reported as a "curtain" or "film" which is not superficial but hardly bulky. The background seems at times to shine through the interstices of the grey, giving it a sort of transparency. In texture it resembles the *Flächenfarbe* described by Katz¹² and the adaptation-film of Sheppard.¹³

CONCLUSIONS

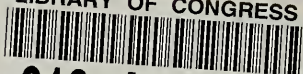
We have, in this investigation, been concerned primarily with a critically descriptive analysis of the reflection in consciousness of a stimulus-complex which is compulsory for the visual perception of movement. We have found that this reflection in consciousness takes the form of a primary integration of a visual quality (grey) with a duration which is characteristically brief. The integration is a multiform grey flash which is independent of the quality of the stimulus but is directly determined by the temporal interval between the exposures of the two stimulus-members. The spatial attribute is a constant factor for any one exposure, but may vary from exposure to exposure (as the perception of movement also varies between optimal and partial). There is, then, no movement in the multiform grey flash; the space is constant; the integration is of time and quality.

Wertheimer, finding that there "is no visual filling-in of the field of movement," argues that the perception of movement must have as its physiological correlate a short-circuit in the cortex. The grey flash which we have found to be the psychological correlate of the perception of movement obviates the necessity of such recourse to novel and speculative conditions.

¹² D. Katz, *Die Erscheinungsweisen der Farben*, 1911, 6ff.

¹³ H. Sheppard, Foveal Adaption of Color, *Amer. Jour. Psy.*, xxxi 1920, 58.

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